1939

STATE COLLEGE OF WASHINGTON
AGRICULTURAL EXPERIMENT STATION
Pullman, Washington

Division of Plant Pathology

Black Root of Sugar Beets in the Puget Sound Section of Washington

by

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Bulletin No. 379

July, 1939

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[1] In cooperation with the State Committee on the Relation of Electricity to Agriculture.
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[3] On leave.

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Black Root of Sugar Beets in the Puget Sound Section of Washington

Leo Campbell[1]

INTRODUCTION

Black root is one of the serious diseases of sugar beets and has been reported from most of the sugar beet growing sections of the United States and Europe. This disease has been of increasing importance in the Puget Sound section of the state of Washington for the past twelve or thirteen years, or since a few years after the inception of the sugar beet industry there. The disease has increased in importance during the last few years until it has become a prime factor in limiting the sugar beet production.

In an investigation during the summer of 1937, black root was found in all of 117 fields examined, ranging in extent from a trace to 95 per cent, and losses due to the disease varied accordingly, or from little or no loss to losses so heavy that fields were abandoned. Similar findings were made from fewer fields examined during the summer of 1938. Losses from the disease are measured in the form of poor stands and retarded growth of surviving plants, both factors contributing to lower yields.

SYMPTOMS AND EFFECTS OF BLACK ROOT

Black root is a seedling disease that is first in evidence because of poor stands (Fig. 1). On examination of blank spaces in the rows, the seedlings that failed to come up will be found to have decayed before they could reach the surface of the soil. Of the plants that emerge, some are attacked at or some distance below the suface of the soil. These diseased plants can be distinguished in the row by a characteristic downward bowing of the petioles (Fig. 2), as described by Nuckols and Tompkins[2] and by retarded growth and general yellowing, as compared with the erect, green and vigorous growth of the healthy plants. The invaded root (or hypocotyl) becomes brownish, then blackened, a symptom from which the characteristic name "black root" was derived (Fig. 2). If the surface of the soil remains

[1] The author gratefully acknowledges the many helpful suggestions and criticisms of Dr. F D. Heald, under whose direction this investigation was conducted, and especially valuable counsel in the preparation of this manuscript. Special thanks are extended to the officials of the Utah-Idaho Sugar Company for laboratory facilities and for encouragement and assistance during the progress of the work; also to farmers in the Bellingham district who have aided the work in various ways.

[2] Nuckols, S. B. and Tompkins, C. M. An undescribed leaf condition associated with damping-off diseases of sugar-beet seedlings. Phytopath. **19**: 317-318. 1929

Fig. 1. Portion of beet field after thinning showing a poor stand as the result of black root, 1938.

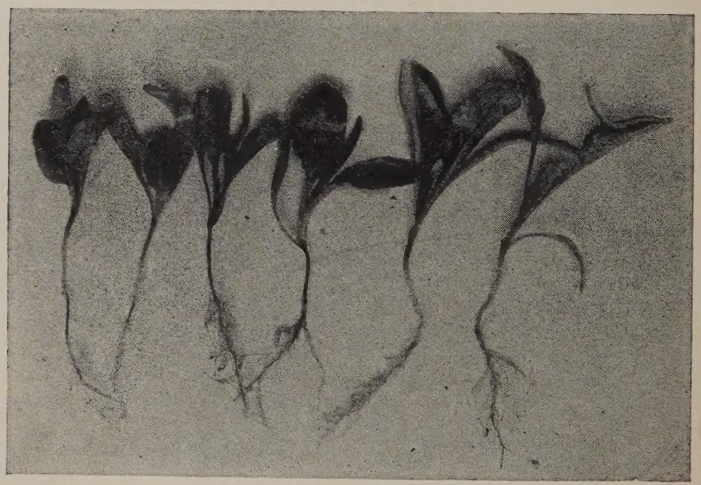

Fig. 2. Seedling beets showing symptoms of black root: lower portion attacked at left, associated with dry weather, and attack of hypocotyl and bowing of the petioles at center, associated with moist weather. Two healthy seedlings at right.

moist, the diseased plants may remain alive for several days, but if the weather turns dry, the invaded root withers to a mere thread and the plants wilt and dry up. If the seedlings are severely attacked, they readily break off immediately below the base of the leaves, even before they wilt. Comparatively few black root plants survive, but those that do live make little growth until late in the summer.

THE CAUSE OF BLACK ROOT

There is a very extensive literature dealing with damping-off diseases of sugar beets, which have quite commonly been designated as black root. No attempt will be made to review this literature, but it may be stated that one or more of five different fungi, namely, *Phoma betae* (Oud.) Fr., *Rhizoctonia solani* Kühn, *Pythium de baryanum* Hesse, *Alphanomyces cochlioides* Drech. and *Fusarium* sp., have been reported to cause the black root of sugar beets.

As a result of the investigations of this disease over the last two years in the Puget Sound district, 31 different fungi have been isolated by numerous cultures from black-root beets collected through the district. In testing the pathogenicity of these fungi, soil in six-inch pots was autoclaved at 15 pounds pressure twice with a two-day interval in each of two tests. The soil was inoculated, one pot for each of the 31 isolates in each test, and each planted to 20 seed balls of domestic stock, previously found to be free from pathogenetic fungi. Results of these tests are presented in Table 1. All except one of these associated fungi have been shown to be only saprophytic invaders. The only isolation found to be pathogenic was a Phoma and it occurred very frequently in the isolation cultures. It was the only one of the organisms previously reported to cause black root to be found in any of the cultures. This fungus agrees with the descriptions given of *Phoma betae* and was found to be identical with Phoma found on beet seed balls of German origin used in this section previous to 1938. The fungus is carried on the seed balls and was, no doubt, introduced into this section of the state in this way, but it may also be indigenous. In either case, the organism accumulates in the soil where beets are grown a few years in succession and serious losses from black root result.

CONTROL OF BLACK ROOT

Repeated attempts on the control of black root have been made, and a reasonable degree of control has been accomplished in several sugar beet-producing sections of the United States and Europe by seed treatment and crop rotation. Of the several treatments tested, dusting the seed with Ceresan generally has given best results[1]. In-

[1] LeClerg, E. L. Treatment of sugar-beet seed increases stand and yield. Minn. Agr. Exp Sta. Circ. 57: 1-7. 1937

Table 1. Results of Inoculation Tests during the Winters of 1937-38 and 1939-40, with Fungi Isolated from Black Root Seedlings Collected from Fields in 1937 and 1938

1937-38

Isolate number	First test*		Second test	
	No. black root plants	No. healthy plants	No. black root plants	No. healthy plants
1	0	34	0	27
2	10	12	0	26
4	0	35	0	27
20	0	33	0	29
22	4	24	0	30
34	4	33	0	27
73	4	32	0	26
77	0	33	0	30
82	0	30	0	26
84	0	26	0	34
91	13	8	17	3
111	0	30	0	35
118	0	26	0	30
119	6	23	0	24
123	0	34	0	26
143	0	27	0	30
167	0	18	0	21
177	0	34	0	30
184	0	35	0	27
185	0	35	0	30
207	0	33	0	28
208	0	34	0	24
210	0	30	0	27
211	0	30	0	27
212	0	26	0	28
1938-39				
215	0	33	0	29
217	0	26	0	20
220	0	20	0	23
223	0	25	0	22
228	0	22	0	25
230	0	30	0	21
C	7	23	0	25
C	0	32	0	24

* The fungi isolated from black root seedlings in the first test were not the same as used in inoculation, but were Pythium, except in 91 when Phoma, the same fungus as used in inoculation was isolated. The soil was apparently insufficiently sterilized.

creases in the unthinned stand of 80 per cent or of more than 30 per cent of the stand at harvest time, and in yields of more than one and one-half tons of beets per acre, have been reported as the result of seed treatment with Ceresan. A system of crop rotation that provides several years interval between beet crops on a given soil, or a small grain crop to precede beets, is commonly recommended.

CONTROL BY CROP ROTATION

From data collected during the growing season of 1937 and 1938, it is evident that black root can be controlled by the proper system of crop rotation. Where beets are grown for two or more years in succession, black root in serious proportions is inevitable, at least on the better beet soils. The object in crop rotation is to prevent the accumulation of, or to rid the soil of the black-root organisms, and to maintain the fertility of the soil. To prevent the accumulation of the black-root organisms, or to rid the soil of them, a cultivated crop immune to the disease should precede beets. This crop makes it possible to cultivate the soil and keep the surface sufficiently dry to apparently kill out, or prevent the accumulation of the black-root organisms. Small grains seem to be rather effective in this respect, but the following beet crop is generally not so good. To maintain the fertility of the soil, a sod crop, either meadow or pasture, containing some legumes should be used. It has been found that a sod crop will harbor the disease for several years, in some cases up to 12 years, and that a cultivated crop such as corn, beans or potatoes generally will reduce it to a safe minimum in one year. Consequently, the cultivated crop should intervene between the sod and beet crop. This order also would facilitate the preparation of the proper seed bed for planting beets. There is some evidence to indicate that longer and smoother beets are produced when beets are grown for several successive years in the same soil. If this evidence is substantiated by further findings, investigations should be conducted to determine the crop, or crops, to be used in the rotation that would be conducive to longer and smoother beets and still function in keeping down black root.

CONTROL BY USE OF SEED FUNGICIDES AND SOIL TREATMENTS

Under certain conditions it is impractical to follow a system of crop rotation as described above, and because of the evidence that better beets are produced when grown for several successive years in the same soil, some alternative to crop rotation for the control of black root is desired by the growers. Consequently, several of the seed treatments used in other sections of the United States for the control of black root were tested in the Puget Sound district, in

cooperation with the Utah-Idaho Sugar Company and local growers

Results in 1937. Three plots of approximately five acres each were devoted to tests of four different dry or dust seed treatments as follows: (1) Equal parts of copper carbonate, mercuric chloride and urea, used at the rate of four ounces to 15 pounds of seed; (2) copper carbonate, four ounces to 15 pounds of seed; (3) two per cent Ceresan, three ounces to 15 pounds of seed; and (4) Ceresan two parts, and copper carbonate one part at the rate of three ounces to 15 pounds of seed. Two or three replications of four or eight rows of each treatment were seeded with ample checks of untreated seed. Counts on the unthinned stands were not made, but no difference in the stands in the unthinned rows could be noticed between the untreated and treated. Black root counts were made by exam-

Table 2. Effect of Varous Dust Treatments of Seed on Black Root and Stand. Season, 1937

Treatment*	1	2	3	4	C
Per cent black root	71.7	73.0	73.3	78.3	76.6
Per cent stand	85.4	88.1	92.0	87.1	90.5

* The seed treatments used are represented by the figures and letter as follows: 1, equal parts of copper carbonate, mercuric chloride and urea; 2, copper carbonate; 3, two per cent Ceresan; 4, two parts of Ceresan and 1 part of copper carbonate; and C, untreated checks.

ining numerous samples of seedlings from representative points in each replication of each treatment. Black root was found to the extent of from 60 to 90 per cent in the three plots, and with no correlation with any of the treatments used. Weights on yields were not taken in any of the plots. In one plot comprising close to five acres, counts on the stand in one row in each replication were made just before harvest, and the results, together with the black root counts, are given in Table 2.

About half of the plot, represented at the left in the table, was in beets for the second successive year, while the other half, represented at the right of the table, was in beets for the third successive year, a condition which is considered to account for the greater amount of black root in the latter. The stands were much better than would be expected and are not indicative of the percentage of black root. The surprisingly good stand is accounted for by the care taken to leave the healthy or most vigorous plants in the process of thinning, especially in the portion of the field where black root was most serious. The majority of the plants making up the stand had been affected with black root but had recovered, as was easily determined during the summer.

From these tests it is concluded that none of the treatments used were of any value in the control of black root under these conditions of heavy soil infestation, and had the beets in this plot been thinned by contract as is ordinarily done in the commercial fields, with no special care to leave the healthy or the more vigorous plants, the crop would no doubt have been a failure. One of the three plots was thinned by contract and, as a result, the thinned stand was so poor that part of the plot was disked up, while the remaining part yielded at the rate of only 8.3 tons per acre.

Results in 1938. In the spring of 1938, three main plots were established for the primary purpose of testing three materials that, of many tested in the greenhouse, showed promise of controlling black root. The plots were designated as the Polinder plot, located just south of Lynden; the Monson plot, located just west of Demming; and the Rasmussen plot, located at Florence. All three plots were on good river-bottom soil where beets had been grown for three or more years in succession, and where black root was serious in 1937. In the Polinder plot each treatment comprised two sections of sixteen forty-foot rows in replication and the checks comprised four 320-foot rows for the full length of the plot. In the Monson plot each treatment and the checks comprised sixteen forty-foot rows in replication. In the Rasmussen plot the formaldehyde dust section, the borax section and the checks each comprised two 690-foot rows, and the calcium cyanamide section twenty twenty-seven-foot rows. Where calcium cyanamide was used, 48 per cent superphosphate, at the rate of 300 pounds per acre, and 50 per cent muriate of potash, at the rate of 200 pounds per acre, were broadcast immediately before planting. With the other fungicides and the checks, 3-10-7 fertilizer was added at the rate of 150 pounds per acre in the drill at planting time. The percentage of black root was taken at thinning time from representative points in each replication of each treatment. Data on these experiments are presented in Table 3.

These results indicate that these treatments were of little or no value in the control of black root as used under the conditions which prevailed.

In cooperation with the Utah-Idaho Sugar Company, two other plots of approximately one acre each were set up. These were planned for the purpose of investigating the value of Ceresan seed treatments in the control of black root, the comparative merits of five different varieties of beets, the value of various amounts of manganese and boron, the importance of the time of planting, and the comparative value of three different seed ball sizes in sugar beet production. In the seed treatment section, two per cent Ceresan and New Improved Ceresan were compared with untreated checks, and

Table 3. Results of Field Tests on the Control of Black Root of Sugar Beets in Whatcom and Snohomish Counties, Washington. Season, 1938

	Polinder Plot				
Treatment*	Cn	Fd	C	Bx	Ce
Number of plants	425	376	413	401	509
Number of black root plants	346	289	357	292	432
Per cent black root plants	81.6	76.8	86.2	72.8	84.8
	Monson Plot				
Treatment*	Cn	Fd	C	Bx	Ce
Number of plants	413	233	322	328	303
Number of black root plants	373	146	277	282	259
Per cent black root plants	81.3	62.6	86.0	85.9	85.4
	Rasmussen Plot				
Treatment*	Cn	Fd	C	Bx	Ce
Number of plants	100	100	100	100	100
Number of black root plants	16	26	17	13	22
Per cent black root plants	16	26	17	13	22
Average per cent black root	78.3	67.0	77.9	70.8	78.1

* The treatments represented by the symbols were as follows: Cn, calcium cyanamide, broadcast at the rate of 500 pounds per acre 16 to 19 days before planting; Fd, formaldehyde dust (6 per cent with charcoal as a carrier) at the rate of 50 pounds per acre with the fertilizer in the drill at planting time; C, untreated checks; Bx, borax at the rate of five pounds per acre with the fertilizer in the drill; Ce, Ceresan dust at rate of 3-4 ozs. to 20 lbs. of seed.

two per cent Ceresan was run in comparison with untreated checks as subplots in a split plot design in the variety test section and in the manganese-boron section. With the exception of the variety test section, seed of the variety U.S. 33 was used. All the seed used in the time of planting sections was treated with two per cent Ceresan, while the seed used in sections for testing the various sizes of seed balls was all untreated. Consequently, these two sections will not be further considered here as only the data given in Table 4 have a significant bearing on black root. The two per cent Ceresan was used at the rate of approximately four ounces per 17 pounds of seed, and the New Improved at the rate of two and one-half ounces, which was about the amount of seed used per acre.

In these plots, the unthinned stand was derived by subtracting the number of blank inch spaces from a representative 100 inches of an inside row of each subplot. The thinned stand represents the number of beets in 100 feet of an inside row of each subplot after the plants had recovered from thinning, the aim being to thin the plants to one plant per foot. The percentage of black root represents the number of black root plants among ten plants from ten representative points of an inside row of each subplot. The yield per acre was derived from the weight of beets from sixty feet of each of the two inside rows at harvest time, where the growth and

Table 4. Field Data on Seed Treatment for Black Root of Sugar Beets. Season, 1938

Treatment*	Unthinned stand	Thinned stand	Per cent black root	Yield, tons per acre
	Whatcom County Plots			
Ceresan	93.3	98.7	7.6	16.4
New Improved Ceresan	92.5	100.0	6.0	15.6
Untreated checks	87.7	68.1	10.6	15.4
	Skagit County Plots			
Ceresan	93.1	99.9	5.1	23.8
New Improved Ceresan	93.0	98.3	5.3	26.4
Untreated checks	90.5	97.8	7.6	22.8
	Averages			
Ceresan	93.2	99.3	6.6	19.6
New Improved Ceresan	92.7	99.3	5.6	21.0
Untreated checks	89.1	99.1	9.1	19.1

* The total length of the rows used in the two plots was as follows: Ceresan, 25,408 feet; New Improved Ceresan, 8,224 feet; and Controls, 25,408, feet.

stand appeared about average for each subplot. The Whatcom plot was located a few miles east of Lynden, and the Skagit plot a few miles west of Conway, in each case on what was considered good beet land. Neither field had grown beets for several years, and black root was not expected to be serious in either. The results of these experiments are presented in Table 4.

The plants came up a little sooner and much more uniformly in the rows for which treated seed was used, but it is evident that both Ceresan and New Improved Ceresan were of but little value in the control of black root. Although there was a slight increase in the unthinned stand and black root-free plants where either of the seed treatments were used, the increase in the thinned stand and yields where seed was treated are considered insignificant. Special care was taken in thinning to leave vigorous plants, but had the thinning been done on the ordinary contract bases, the difference in the thinned stand and yield per acre would no doubt have been greater and the value of Ceresan treatments more significantly demonstrated.

CONCLUSIONS

None of the treatments used during the two years of investigations gave any significant control of black root where the soil was heavily infested. If any of the materials used gave any protection, it was not for the full duration of the pre-emergent growth of the seedlings, and there was no indication of any protection after the plants emerged. Where black root was not sufficiently severe to be of any economic importance, some protection against the pre-emergent stage of the disease was indicated by the use of two per cent Ceresan or New Improved Ceresan. From these tests it would seem that either of the Ceresans should be of considerable value as an insurance of better stands where the severity of the disease is intermediate between the two extremes as here reported (25 to 50 per cent black root).

Until some direct method of controlling the post-emergent stage of black root is developed, a system of crop rotation, as described above, together with Ceresan seed treatment, is recommended. The investigations are being continued with the hopes of developing an economic control of the post-emergent stage of black root under field conditions. The general use of domestic seed in this district is expected to be an important factor in the control of the disease, since this seed has not been found to carry Phoma.